PEACE/WILLISTON
FISH & WILDLIFE
COMPENSATION
PROGRAM

BCHydro

BRITISH
COLUMBIA

An Updated Review of Grayling Biology, Impacts, and Management

Dr Tom G. Northcote
February 2000

PWFWCP Report No. 211

105-02257/

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave. 3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.bc.ca/environment/initiatives/pwcp/*

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

Citation: Dr Tom G. Northcote. February 2000. An updated review of grayling biology, impacts, and management. Peace/Williston Fish and Wildlife Compensation Program, Report No. 211. 24pp plus appendices.

Author(s): Thomas G. Northcote[1]

Address(es): [1] Professor Emeritus, Department of Zoology, UBC
c/o RR2 S77B C2, Summerland, BC V0H 1Z0

PREFACE

This report originated from a presentation by Dr. Tom Northcote at the Arctic Grayling Workshop sponsored by the Peace/Williston Fish and Wildlife Compensation Program. The Workshop occurred on January 18 to 20, 2000, in Prince George, BC. The intent of this workshop was to gather data on Arctic grayling from British Columbia, Alberta, Northwest Territories, and Montana, USA. In addition, there was an exchange of ideas from many biologists discussing habitat preferences of Arctic grayling, harvest regulations, and basic biology (population dynamics, genetics, and community interactions). With all of this information, the future management of this species will be further defined and ultimately ensure the longevity of this species of special concern.

Dr. Tom Northcote was a keynote speaker at this workshop and has agreed to provide the Peace/Williston Fish and Wildlife Compensation Program with a condensed version of his presentation. The abstract for this presentation is also published in the Peace/Williston Fish and Wildlife Compensation Program report series No.210 titled "Arctic Grayling Workshop 2000". In addition, at the end of this report is a list or references compiled by Dr. Tom Northcote illustrating a literature review on Arctic grayling.

AN UPDATED REVIEW OF GRAYLING BIOLOGY, IMPACTS, AND MANAGEMENT

Thomas G. Northcote
Professor Emeritus
Department of Zoology, UBC
c/o RR2 S77B C2, Summerland, B.C., VOH 1ZO
January 2000

INTRODUCTION

One might well question why yet another such review is needed. After all, I had reviewed this area with special reference to the Williston Reservoir watershed of British Columbia in the early 1990s (Northcote 1993), and followed it up shortly thereafter with a comparison of the biology and management of Arctic and European grayling (Northcote 1995).

The most compelling reason is that there has been an almost exponential increase in relevant grayling literature over the past few years. I found some 180 new references to my previous reviews, 122 of them since the mid 1990s, and I was by no means able to cover much of the "grey literature" in the time available, or to contact all of the active groups working in this field. In addition, more information is becoming available on Siberian / Asian populations of Arctic grayling, and on grayling in the Amur Basin as well as in Mongolia that is of great interest.

Armin Peter at the Swiss Federal Institute for Water Resources and Water Pollution Control, Kastanienbaum, kindly arranged a literature search for me on grayling references since 1994. Abigail Ingram, Institute of Freshwater Ecology, Wareham, England sent me her European grayling references, as did Henri Persat, University of Lyon, France and Michael Dedual, Switzerland (now New Zealand). Doug Fleming, Alaska State Fish and Wildlife, provided me with an update of much of the work going on there. Mrs. Lisa Northcote arranged for my use of NIWA library facilities in Wellington, New Zealand. Joe Nelson and Bill Tonn, University of Alberta, Edmonton also helped, as did many others. I would be most grateful to receive information on work missed or on new studies becoming available.

My interest in grayling began in 1952 when I had the opportunity, conducting limnological studies in northeastern B.C. for Peter Larkin, then Chief Fishery Biologist of the B.C. Game Commission, to see the Pine River grayling habitat and sample its fine grayling populations. Later in the 1970s I visited Arctic grayling habitat in the Angara River (outlet of Lake Baikal, Siberia) and saw the intensive "sport" fisheries there heavily dependent on grayling snagging. In 1993 I went back again to the upper Peace River tributaries, working on snorkeling census of grayling on the Burnt and Sukunka rivers, and in the mid 1990s enjoyed dry fly fishing for grayling there.

GRAYLING WORLD DISTRIBUTION

Arctic grayling, now extinct as natural populations in the Michigan area (Fig. 1), and in their most southern limits reduced at present to the Big Hole River system in the upper Missouri River, are broadly distributed across northern Canada from western drainages into Hudson Bay, through Alaska, across the Bering Strait into far Eastern Siberia and

"condensed from an invited keynote address 20 January 2000 at the Arctic Grayling Workshop sponsored by the Peace/Williston Fish and Wildlife Compensation Program

Kamchatka, through Siberia westward to the eastern slopes of the Ural Mountains where they contact the European grayling.

The latter as native populations extend throughout most of Europe to western France, much of Scandinavia and England and southern Scotland. Graylings of uncertain taxonomic status are found in the mid and upper Amur River basin (Fig. 1) and in parts of Mongolia.

THE GRAYLING LITERATURE

The decline in publication rate on Arctic grayling in the Michigan area since the mid 1880s has been counterbalanced by an increase in all other major parts of its range since then (Fig. 2), slowly in the Montana and Siberia / Asia areas, and much more rapidly in Canada / Alaska especially in the most recent decade.

The 186 grayling references that I reviewed can be partitioned into four broad subject areas, recognizing that some of these fit into two or more of the areas (Fig. 3). By far the most (158 out of the 186) deal with biological studies on grayling, about equally so for Arctic and European grayling, with a very few on Amur / Mongolian graylings. Some 42 consider environmental impacts on grayling (equally so for the Arctic and European species), 38 on fishery effects (heavily for Arctic, less so for European and Amur / Mongolian graylings), and 46 on management activities (nearly equally for Arctic and European graylings). Siberian / Asian Arctic grayling make small contributions to total percentages for all four subject areas (Fig. 3).

1. Grayling biology

The literature included in this review comes largely from that appearing after my 1993 and 1995 coverage although some references that I had missed then are added as well as a few others given previously of special interest. The references on Arctic, European and Amur / Mongolian grayling are first placed into four broad subject areas - biological studies, environmental impacts, fishery effects, and management activities as indicated respectively by the Roman numerals in squared brackets at the end of each one in the reference list. Two subject areas are further partitioned - biological studies into seven categories and management activities into four, as indicated by the Arabic numbers in normal parentheses behind the appropriate Roman numerals.

Recent references on grayling biology partitioned into the seven subject areas are shown in Figure 4. There are 44 on grayling species, stocks and genetics (most for Arctic grayling), 64 on estimates of population size and regulating factors (most again for Arctic grayling), 39 on habitat use and conditions (most for European grayling), 31 on spawning and development up to the emergence stage (about equal for Arctic and European grayling), 52 on various aspects of age, size and growth (far more for Arctic than for European or Amur / Mongolian grayling), 40 on movements, migrations and homing (most for Arctic grayling), and 20 on feeding (most for Arctic grayling).

Species, stocks and genetic references deal with morphological aspects (dorsal fin patterns, gill rakers), parasite faunas, growth rates, juvenile current responses, mitochondrial and nuclear DNA, and allozymes all of which show high regional differences. There will soon be a further upsurge of publications in this area with several groups input, some on Amur and Mongolian grayling.

The many studies on population size and its regulation include both field and laboratory work showing the role of competitive interaction and microhabitat segregation for several Arctic and European grayling populations. Also included are field studies on predation (pike, burbot, cormorants) in population regulation especially for European and Lake Baikal Arctic grayling.

A number of detailed field studies (some experimental) show the importance of shoreline, bank, and small tributary habitat for young grayling. Quantitative data are becoming available now on velocity, depth, substrate, and cover requirements for both Arctic and

European grayling. The marked shifts being demonstrated with day / night, season, and age / size all have high management significance.

Along with the many field studies on spawning, hatching and emergence of Arctic grayling, there is one of the first for northeastern Siberian and Okhotsk rivers. The first demonstration of night spawning using hydrophones and acoustic gear has been made for French stream populations. Other good field studies in this area for European grayling are coming from Belgian, Swiss and Norwegian populations.

Enclosure studies (Big Hole River, Montana) are showing that intraspecific competition has a greater negative effect on growth rate than does interspecific (brook trout) competition. Electrofishing is shown to decrease growth rates of Arctic grayling (experimental studies, Montana, Alaska stream populations). Several studies give broad coverage of size, age and growth for Siberian Arctic grayling, as well as for European grayling populations (UK, France, Norway), and a few for Amur / Mongolian grayling populations.

Field studies show patterns ofjuvenile migration from spawning to feeding habitats for Arctic grayling (including two Siberian populations), along with field and experimental work on French, Swiss, Norwegian, Swedish and western Russian populations of European grayling. Precise homing (radiotelemetry) has been demonstrated for Belgian populations with upstream spawning migrations of some 5 km and downstream return to the same pool / riffle sequence. In the upper Volga system, homing is shown to be 83 %.

The fewer feeding studies include experimental work on Alaska stream populations of Arctic grayling (modelling of drift feeding) and on Siberian reservoirs and rivers, for European grayling in Norwegian reservoirs and French rivers, and for Amur River basin grayling.

2. Environmental impacts

Studies on impoundments and diversions continue to dominate work in this area for both Arctic and European grayling. Bypass channels are showing promise of allowing effective grayling movement in Austrian rivers with suitable profile characteristics.

Pollution associated with organochlorine pesticides and heavy metals temporarily bound in sediments are sources of much contamination in both North American and Siberian Arctic grayling populations. In the later, levels are high enough to cause structural abnormalities. Sockeye salmon adults are shown to biotransport PCBs and DDT from marine sources to inland Alaskan Arctic grayling that have over two times higher the level than those populations with no salmon. Impaired feeding ability (up to 25 % lower) has been demonstrated in European grayling fry with relatively low induced levels (less than 3 µg / L) of methylmercury. Such levels can occur by diffuse atmospheric fallout. Increased aquatic iron and aluminum levels caused by forest harvesting can have harmful effects on Finnish European grayling.

3. Sport fishing effects

Catch and release fisheries are developing for the presently large eastern Siberian Arctic grayling. For many of these populations there are high incidences (up to 41 %) ofjaw damage attesting to heavy overfishing and snagging effects.

In some heavily fished Swiss populations of European grayling there are very few older fish (94 % less than two years old, and 99.7 % less than three years old!). On a popular Norwegian river, angling hours per river kilometre may reach 2000 annually. In north England rivers overfishing and "culling" are listed as important causes of grayling decline. Overfishing occurs in tributaries of the Pechora River in the northwestern Urals.

For Amur grayling populations commercial fisheries in the late 1800s may have had serious effects as catches up to 27,000 kg are recorded from an upper basin tributary with

high catches of large grayling also being taken by anglers in the recent decades. Individuals up to nearly 2 kg can still be caught in that system.

4. Management activities

Some 42 recent references on grayling management can be partitioned into four main subject areas (Fig. 5), most on aquaculture / stocking, less on habitat restoration, and a few on angling regulations and on competitor or predator control.

Aquaculture, especially for European grayling in Sweden and elsewhere, is well developed with a recent doctoral thesis and many journal publications dealing with methods, feeds, and stocking results.

Catch and release angling is on the rise, particularly in the UK, but apparently not so in Siberia / Asia for Arctic grayling or for Amur / Mongolian grayling, except for that by European angling tour groups.

Stream habitat restoration specifically for Arctic grayling is showing great promise especially in Montana but also in B.C., Alberta, and Alaska, as well as for European grayling in parts of continental Europe (e.g. in Switzerland and Austria).

Migration bypass channels are being developed for European grayling blocked by weirs and dams in some parts of continental Europe where river profiles are suitable.

GRAYLING MANAGEMENT IN B.C. WILLISTON / DINOSAUR RESERVOIRS

Success will demand assertive approaches on four main fronts.

1. Fill serious gaps in basic grayling biology

Stock / metapopulation / genetic diversity work needs to be continued and if anything intensified with its management implications being clearly and specifically identified.

Quantitative population size data for all age groups of several key systems still are needed, as are quantitative habitat use data for these, with careful attention being given to changes with size, day / night, season, spawning, feeding, and refuge (e.g. overwintering) habitats.

The extent and locality of spawning, feeding and refuge migrations need to be carefully defined as well as the precision of homing to these habitats.

2. Limit negative environmental impacts

Present and future impoundment agencies must support effective, well-documented and quantitative compensatory work on the needs listed above and below.

Forest harvesting and associated other road development has high potential for multiple serious impacts which must be addressed before such work starts.

3. Apply promising management practices on grayling populations, habitats and fisheries

There would seem to be no urgent need for grayling hatcheries or stocking except perhaps in a few special cases.

As angling and other pressures mount, even more restrictive angling regulations will be needed. Catch and release fisheries would seem to be the only way to prevent severe stock depletion where angling intensity is high, and the only way to keep large colourful adults in the population. Even such practices may well have harmful sublethal but accumulative effects on populations.

Tests should be made (with adequate before documentation and after evaluation) of stream restoration / enhancement for spawning, rearing and overwintering in two or three key systems.

The one stream fertilization study needs to be well documented statistically and if the apparently promising results obtained so far stand up, extended to a few other key systems.

Where migration route problems are demonstrated, means of improvement / rectification must be used or if necessary developed.

4. Provide public with meaningful opportunities to understand and appreciate grayling

The information available on the successful work in this area by The Grayling Society in the UK, which in little more than a decade has turned the European grayling there from a "coarse" fish to be eradicated into a highly appreciated sport fish, needs to be carefully examined.

Forums, workshops, educational talks and material, and field tours should be provided regularly for the angling public, the resource agency staff, and for developers.

Good luck! It's a challenging task, but "The Lady of the Stream" is counting on you, and is surely more than worthy of the very best efforts!

REFERENCES

Allen, G.S.M., Gubala, C.P., Landers, D.H., Lasorea, B.K., Crecelius, E.A. and Curtis, L.R. 1997. Heavy metal accumulation in sediment and freshwater fish in U.S. Arctic lakes. Environmental Toxicology and Chemistry 16(4): 733-741. [II]

Allen, G.S.M., Gubula, C.P., Wilson, R., Landers, D.H., Wade, T.L., Sericano, J.L. and Curtis, L.R. 1997. Organochlorine pesticides and polychlorinated biphenyls (PCBs) in sediment and biota from four US Arctic lakes. Archives of Environmental Contamination and Toxicology 33(4): 378-387. [II]

Anonymous. 1995. Montana fluvial Arctic grayling Workgroup, Montana fluvial Arctic grayling restoration plan. 20 pages. [I (1,2,6); II; IV (1,2)]

Anonymous. 1998. Biologists intensify efforts to save popular game fish in Williston Reservoir watershed. Natureline Issue No. 9: 1,4. [I (1,3,4,6); IV (2)]

Antonov, A.L. 1995. Grayling (Genus *Thymallus*) of the Bureya River (Amur River Basin). Journal of Ichthyology 35 (9): 374-378. [I (1)]

Bardonnet, A. and Gaudin, P. 1991. Influence of daily variations of light and temperature on the emergence rhythm of grayling fry *(Thymallus thymallus*). Canadian Journal of Fisheries and Aquatic Sciences 48: 1177-1180. [I (4)]

Bardonnet, A., Gaudin, P. and Persat, H. 1991. Microhabitats and diel downstream migration of young grayling *(Thymallus thymallus* L.). Freshwater Biology 26: 365-376. [I (3,6)]

Barndt, S.A. and Kaya, C.M. 1999 MS. Reproduction, growth, and winter habitat of Arctic grayling in an intermittent canal. Submitted to Northwest Science. [I (3,4,5); II]

Berry, D.K. 1998. Alberta's Arctic grayling management and recovery plan. Alberta Environmental Protection, Fisheries Management Division, Edmonton, Alberta. 27 pages. [IV (1,3)]

Bosch, D.E. 1995. Population dynamics and stock assessment of Arctic grayling *(Thymallus arcticus)* in the Gulkana River drainage, Alaska. Masters thesis, University of Alaska, Fairbanks. [I (1,2,5); III]

Bouvet, Y., Soewardi, K. and Pattee, E. 1990. Genetic divergence within natural populations of grayling *(Thymallus thymallus)* from two French river systems. Achiv fur Hydrobiologie 119: 89-101. [I (1)]

Bouvet, Y., Pattee, E. and Maslin, J.L. 1992. A comparison of the genetic variability of two fish species, grayling *Thymallus thymallus* and roach *Rutilus rutilus* , in a large regulated river. Bulletin Francais de la Peche et de la Pisciculture 319: 26-35. [I (1); II]

Bristow, A. 1998. Mongolian grayling. The Grayling Society Journal, Spring 1998: 10-12. [III]

Budihna, N. and Oevirk, A. 1990. Breeding and restocking of salmonid fishes in Slovenia. Journal of Fish Biology 37 (Supplement A): 239-240. [III; IV (1)]

Byorth, P.A. 1991. Population surveys and analysis of fall and winter movements of grayling in the Big Hole River: 1991 Annual Report, Fluvial Arctic Grayling Workgroup, Helena, Montana. [I (2,6)]

Byorth, P.A. 1992. Big Hole Arctic grayling restoration project work plan: 1992-1995. Fluvial Arctic Grayling Workgroup, Montana Fish, Wildlife and Parks, Report. [IV (1,2)]

Byorth, P.A. and Magee, J.P. 1998. Competitive interactions between Arctic grayling and brook trout in the Big Hole River drainage, Montana. Transactions of the American Fisheries Society 127: 921-931. [I (2,3,5)]

Carlstein, M. 1993. Natural food and artificial, dry starter diets: effects on growth and survival in intensively reared European grayling. Aquaculture International 1: 112-123. [IV (1)]

Carlstein, M. 1995. Growth and survival of European grayling reared at different stocking densities. Aquaculture International 3 (3): 260-264. [IV (1)]

Carlstein, M. 1996. Feeding, growth and survival of European grayling in culture and after stocking. Doctoral thesis, Swedish University of Agricultural Sciences, Umea, Sweden. 155 pages. [IV (1)]

Carlstein, M. 1997. Effects of rearing techniques and fish size on post-stocking growth and survival of European grayling, *Thymallus thymallus* (L.). Fisheries Management and Ecology 4 (5): 391-404. [IV (1)]

Carlstein, M. and Eriksson, L.O. 1996. Post-stocking dispersal of European grayling, *Thymallus thymallus* (L.) in a semi-natural experimental stream. Fisheries Management and Ecology 3 (2): 143-155. [I (6); IV (1)]

Cios, S. 1998. Grayling fishing-historical notes. The Grayling Society Journal, Autumn 1998: 36-37. [III]

Clark, R.A. 1992. Influence of stream flows and stock size on recruitment of Arctic grayling *(Thymallus arcticus*) in the Chena River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 49: 1027-1034. [I (4)]

Clark, R.A. 1994a. Population dynamics and potential utility per recruit of Arctic grayling in Fielding Lake, Alaska. North American Journal of Fisheries Management 14(3): 500-515. [I(2);III]

Clark, R.A. 1994b. Stock assessment of Arctic grayling in Fielding Lake from 1986 to 1993. Alaska Department of Fish and Game, Fisheries Manuscript No. 94-2, Anchorage, Alaska. [I (1,2,5); III]

Clark, R.A. 1994c. Stock status and rehabilitation of Chena River Arctic grayling during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-5, Anchorage, Alaska. [I (1,2); IV (1)]

Clark, R.A. 1995. Stock status and rehabilitation of Chena River Arctic grayling during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-8, Anchorage, Alaska. [I (1,2,5); IV (1)]

Clark, R.A. 1996. Stock status and rehabilitation of Chena River Arctic grayling during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-2, Anchorage, Alaska. [I (1,2,5); IV (1)]

Clark, R.A. and Ridder, W.P. 1994. An age-structured stock analysis of Arctic grayling in the Delta Clearwater River, 1977 to 1990. Alaska Department of Fish and Game, Fishery Manuscript No. 94-4, Anchorage, Alaska. [I (1,2,5); III]

Crisp, D.T. 1996. Environmental requirements of common riverine European salmonid fish species in fresh water with particular reference to physical and chemical aspects. Hydrobiologia 323 (3): 201-221. [I (3)]

Darchambeau, F. and Poncin, P; 1997. Field observations of the spawning behaviour of European grayling. Journal of Fish Biology 51: 1066-1068. [I (4)]

DeCicco, A.L. 1994. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-12, Anchorage, Alaska. [I (2,5)]

DeCicco, A.L. 1995. Assessment of Arctic grayling in selected streams and a survey of Salmon Lake, Seward Peninsula, 1994. Alaska Department of Fish and Game, Fishery Data series No.95-19, Anchorage, Alaska. [I (2,5)]

DeCicco, A.L. 1996. Assessment of Arctic grayling in selected streams of the Seward Peninsula, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-21, Anchorage, Alaska. [I (2,5)]

DeCicco, A.L. 1997. Assessment of Arctic grayling in selected streams of the Seward Peninsula, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-15, Anchorage, Alaska. [I (2,5)]

DeCicco, A.L. 1998. Assessment of Arctic grayling in selected streams of the Seward Peninsula, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-19, Anchorage, Alaska. [I (2,5)]

DeCicco, A.L. 1999. Niukluk River Arctic grayling stock assessment, Seward Peninsula, Alaska, 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-23, Anchorage, Alaska. [I (2,5); IV (1)]

Decicco, A.L., Merritt, M.F. and Bingham, A.E. 1997. Characteristics of a lightly exploited population of Arctic grayling in the Sinuk River, Seward Peninsula, Alaska. Proceedings of the Fish Ecology in Arctic North America Symposium, Fairbanks, Alaska, May 1992. J.B. Reynolds, Editor, American Fisheries Society Symposium 19: 229-239. [I (2,5); III]

Dedual, M. 1998. Capacite d'acceuil physique de la Petite Sarine pour l'ombre commun *(Thymallus thymallus)* et la truite fario *(Salmo trutta)*. Rapport pre'pare' pour la Commission Technique de la Fe'de'ration Cantonale de Peche du Canton de Fribourg. 19 pages. [I (3); IV (2)]

Deegan, L.A., Peterson, B.J., Golden, H., McIvor, C.C. and Miller, M.C. 1997. Effects of fish density and river fertilization on algal standing stock, invertebrate communities, and fish production in an Arctic river. Canadian Journal of Fisheries and Aquatic Sciences 54: 269-283. [I (2); IV (2)]

Deegan, L.A., Golden, H.E., Harvey, CJ. and Peterson, B.J. 1999. Influence of environmental variability on the growth of age-0 and adult Arctic grayling. Transactions of the American Fisheries Society 128: 1163-1175. [I (3,7)]

Deleray, M.A. and Kaya, C.M. 1992. Lakeward and downstream movement of age-0 Arctic grayling *(Thymallus arcticus)* originating between a lake and a waterfall. Great Basin Naturalist 52: 344-351. [I (6)]

Degerman, E. and Sers, B. 1994. The effects of lakes on the stream fish fauna. Ecology of Freshwater Fish 3 (3): 116-122. [I (2)]

Denham, K.L. 1999. Occurrence of *Gyrodactylus thymalli* Zitnan 1960 on grayling, *Thymallus thymallus* (L.), in England. Journal of Fish Diseases 22 (3): 247-252. [I (2)]

Dorovskikh, G.N. 1996. *Cystidicoloides tenuissima* (Nematoda: Ascarophilididae) in host populations of the Mezen river basin. Parazitologiya (St. Petersburg) 30 (4): 357-363.[I (2)]

Durand, S. 1997. The "No Name" River. The Grayling Society Journal, Spring 1997:13-21. [III]

Dwyer, W.P. and White, R.G. 1995. Influence of electroshock on short-term growth of adult rainbow trout and juvenile Arctic grayling and cutthroat trout. North American Journal of Fisheries Management 15 (1): 148-151. [I (5); II]

Dwyer, W.P. and White, R.G. 1997. Eftect of electroshock on juvenile Arctic grayling and Yellowstone cutthroat trout growth. North American Journal of Fisheries Management 17(1): 174-177. [I (5); II]

Eriksen, C. 1975. Physiological ecology and management of the rare "southern" grayling *(Thymallus arcticus tricolor)* Cope. Verhandlungen Internationale Vereinigung fur theoretische und angewandte Limnologie 19 (3): 2448-2455.[IV (2)]

Ewald, G., Larsson, P., Linge, H., Okla, L. and Szarzi, N. 1998. Biotransport of organic pollutants to an inland lake by migrating sockeye salmon *(Oncorhynchus nerka)*. Arctic 51 (1): 40-47. [II]

Feldmeth, C.R. and Eriksen, C.H. 1978. A hypothesis to explain the distribution of native trout in a drainage of Montana's Big Hole River. Verhandlungen Internationale Vereinigung fur theoritische und angewandte Limnologie 20: 2040-2044. [I (3)]

Fish, J.T. 1996. Stock assessment of Arctic grayling in the Chatanika River during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-5, Anchorage, Alaska. [I (2,5)]

Fish, J.T. 1997. Stock assessment of Arctic grayling in the Jim River and other streams adjacent to the Dalton Highway, 1995-1997. Alaska Department of Fish and Game, Fishery Manuscript No. 97-3, Anchorage, Alaska. [[I (2,5); III]

Fish, J.T. 1998. Radio telemetry of Arctic grayling in the Jim River (Dalton Highway) during 1997-1998. Alaska Department of Fish and Game, Fishery Manuscript No. 98-4, Anchorage, Alaska. [I (1,3,4,6,7)]

Fish, J.T. 1999. Age and length composition of Arctic grayling in Mendeltna Creek based upon hook-and-line and electrofishing catches during 1998. Alaska Department of Fish and Game, Fishery Manuscript No. 99-22, Anchorage, Alaska. [I (3,4,5,6,7); III]

Fish, J.T. and Roach, S.M. 1999. Evaluation of the Arctic grayling stock in the Gulkana River, 1998. Alaska Department of Fish and Game, Fishery Manuscript No. 99-28, Anchorage, Alaska. [I (5);III]

Fjeld, E., Haugen, T.O and Vollestad, L.A. 1998. Permanent impairment in the feeding behavior of grayling *(Thymallus thymallus)* exposed to methylmercury during embrogenisis. Science of the Total Environment 213(1-3): 247-254. [I (7); II]

Fleming, D.F. 1994. Stock assessment of Arctic grayling and rainbow trout in Piledriver Slough during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-34, Anchorage, Alaska. [I (2,5); III; IV (3)]

Fleming, D.F. 1995. Stock assessment of Arctic grayling in Piledriver Slough during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-15, Anchorage, Alaska. [I (2,5,6); III

Fleming, D.F. 1997. Stock assessment of Arctic grayling in Piledriver Slough during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-18, Anchorage, Alaska. [I (2,4,5,6); II]

Fleming, D.F. 1998a. Status of the Arctic grayling fishery in the upper Chatanika River during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-29, Anchorage, Alaska. [I (5); II]

Fleming, D.F. 1998b. Stock assessment of Arctic grayling fishery in Piledriver Slough during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-21, Anchorage, Alaska. [I (2,4,5,6); II]

Fleming, D.F. and Reynolds, J.B. 1991. Effects of spawning-run delay on spawning migration of Arctic grayling. American Fisheries Society Symposium 10: 299-305. [I (6)]

Frenz, C., Klinga, H. and Schuhmacher, H. 1997. Interim report on the factors affecting grayling *(Thymallus thymallus* L.) and brown trout *(Salmo trutta* L.) populations in the River Lenne (North Rhine - Westphalia): habitats, cormorants and angling. Nat-Landschaft 72 (9): 401-407. [I (2); III]

Gaedke, U. 1999. The response of the pelagic food web to re-oligotrophication of a large and deep lake (L. Constance): Evidence for scale-dependent heirarchial patterns? In: E. Bauerle and U. Gaedke. [Editors] Lake Constance. Characterization of an ecosystem in transition. Special Issue VII, Archiv fur Hydrobiologie, 610 pages. ISBN 3 - 510 -47055 - 9. [I (3)]

Gardiner, R. 1997. The same fish? The Grayling Society Journal, Spring 1997: 31. [III]

Gaudin, P. and Sempeski, P. 1998. The role of river bank habitat in the early life of fish: the example of grayling, *Thymallus thymallus* . In: M. Zalewski, J.E. Thorpe and F. Schiemer. [Editors]: Fish and Land / Inland Water Ecotones. M.A. B. Series 5. [I (3)]

Gettel, G.M., Deegan, L.A. and Harvey, CJ. 1997. A comparison of whole and thin-sectioned otolith aging techniques and validation of annuli for Arctic grayling. Northwest Science 71 (3): 224-232. [I (5)]

Gibbins, C.N. and Heslop, J. 1998. An evaluation on inter-basin water transfers as a mechanism for augmenting salmonid and grayling habitat in the River Wear, North-east England. Regulated Rivers: Research and Management 14: 357-382. [I (3); IV (2)]

Golden, H.E. and Deegan, L.A. 1998. The trophic interactions of young Arctic grayling *(Thymallus arcticus)* in an arctic tundra stream. Freshwater Biology 39: 637-648. [I (7); IV (2)]

Greenberg, L., Svendsen, P. and Harby, A. 1996. Availability of microhabitats and their use by brown trout *(Salmo trutta*) and grayling *(Thymallus thymallus*) in the River Vojman, Sweden. Regulated Rivers: Research and Management 12: 287-303. [I (3)]

Guthruf, J. 1996. Productiondynamik und Habitatwahl der Aesche *(Thymallus thymallus* L.) in drei verschieden Gewassern des Schweizerischen Mittellandes. These de Doctoral de 1'Ecole Polytechniqu. Fe'de'rale de Zurich. DISS.ETH. No.11720. 180 pages. [I (2,3,4,6); II; III; IV (1,2)]

Hallberg, J.E. and Bingham, A.E. 1996. The Delta Clearwater and Salcha River creel surveys conducted in 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-20, Anchorage, Alaska. [I (5); III]

Hallberg, J.E. and Bingham, A.E. 1997. The Delta Clearwater River creel survey. Alaska Department of Fish and Game, Fishery Data Series No. 97-19, Anchorage, Alaska. [I (5); III]

Haugen, T.O. and Rygg, T.A. 1996a. Food- and habitat-segregation in sympatric grayling and brown trout. Journal of Fish Biology 49: 301-318. [I (2,3,7)]

Haugen, T.O. and Rygg, T.A. 1996b. Intra- and interspecific life history differences in sympatric grayling and brown trout in a Norwegian reservoir. Journal of Fish Biology 48: 964 - 978. [I (2,3,5)]

Heland, M., Gaudin, P. and Bardonnet, A. 1995. First behavioural adjustments in relation to habitat use after emergence in running water salmonids. Bulletin Francais de la Peche et la Pisciculture 338: 191-197. [I (3,4)]

Henricson, J. 1984. Population size of grayling *Thymallus thymallus* (L.) in power generating river reservoirs estimated by catch-recapture methods. Information Reports from the Freshwater Laboratory, Drottningholm, Sweden, 1984 (6), 36 pages. [I (2); II]

Hoci'k, J. 1991. Fish introductions in Europe with particular reference to its central and eastern part. Canadian Journal of Fisheries and Aquatic Sciences 48 (Supplement 1): 13-23. [IV (1)]

Hughes, N. 1998a. Use of whole-stream patterns of age segregation to infer the interannual movements of stream salmonids: a demonstration with Arctic grayling in an interior Alaskan stream. Transactions of the American Fisheries Society 127:1067-1071. [I (5,6)]

Hughes, N. 1998b. Reduction in growth due to electrofishing and tagging may change interannual movement behavior of stream salmonids: evidence from Arctic grayling in an interior Alaskan stream. Transactions of the American Fisheries Society 127: 1072-1077. [I (5,6)]

Hughes, N. 1998c. A model of habitat selection by drift-feeding stream salmonids at different scales. Ecology 79: 281-294. [I (2,7)]

Hughes, N.F. 1999. Population processes responsible for larger-fish-upstream distribution patterns of Arctic grayling *(Thymallus arcticus)* in interior Alaskan runoff rivers. Canadian Journal of Fisheries and Aquatic Sciences 56: 2292-2299. [I (4,5,6)]

Hughes, N.F. and Kelly, L.H. 1996. A hydrodynamic model for estimating the energetic cost of swimming maneuvers from a description of their geometry and dynamics. Canadian Journal of Fisheries and Aquatic Sciences 53: 2484-2493. [I (5,7)]

Hughes, N.F. and Reynolds, J.B. 1994. Why do Arctic grayling get bigger as you go upstream? Canadian Journal of Fisheries and Aquatic Sciences 51: 2154-2163. [I (2,5)]

Humpesch. U.K. 1992. Ecosystem study Altenworth: impacts of a hydroelectric power-station on the River Danube in Austria. Freshwater Forum, Freshwater Biological Association, U.K., Volume 2, Number 1: 33-58. [II]

Ibbotson, A. 1998a. Fluctuations in grayling populations. The Grayling Society Journal, Autumn 1998: 40-43. [I (2); III]

Ibbotson, A.T. 1998b. Year-class strengths and recruitment in a grayling population -1998 sampling. Report to Environmental Agency, South West Region, IFE Report Number 11050J7, November 1998, 6 pages + 12 appendices. [I (4); III]

Jervis, L. and Hirst, S. 1997. Grayling in South West Britain. Part 1. The Grayling Society Journal, Autumn 1997: 33-41. [I (5); II; III; IV (1)]

Jungwirth, M. 1996. Bypass channels at weirs as appropriate aids for fish migration in rhithral rivers. Regulated Rivers: Research and Management 12 (4-5): 483-492. [I (6); II; IV (2)]

Jurajda, P., Hohausova, E., Prasek, V. and Dvorak, M. 1996. Fishes of Pol'ana mountain streams. Biologia (Bratislava) 51 (2): 173-178. [I (2); IV (1)]

Kaya, C.M. 1992a. Restoration of fluvial Arctic grayling to Montana streams: assessment of reintroduction potential of streams in the native range, the upper Missouri River drainage above Great Falls. Prepared for: Montana Chapter, American Fisheries Society, Montana Department of Fish, Wildlife and Parks, US Fish and Wildlife Service, and US Forest Service, Bozeman, Montana. 102 pages. [IV (2)]

Kaya, C.M. 1992b. Review of the decline and status of fluvial Arctic grayling in Montana. Proceedings of the Montana Academy of Sciences 1992: 43-70. [I (2); II; III]

Kaya, C.M. and Jeanes, E.D. 1995. Retention of adaptive rheotactic behavior by fluvial Arctic grayling. Transactions of the American Fisheries Society 124: 453-457. [I (1,6)]

Keller, T. 1998. The food of cormorants *(Phalacrocorax carbo sinensis*) in Bavaria. Journal für Ornithologie 139 (4): 389-400. [I (1,6)]

Kristiansen, H. and Døving, K.B. 1996. The migration of spawning stocks of grayling, *Thymallus thymallus,* in Lake Mjøsa, Norway. Environmental Biology of Fishes 47: 43-50. [I (1,3,6,7)]

Kulikowski, M. and Rokicki, J. 1998. Parasites of grayling *Thymallus thymallus* dwelling in the Pomeranian rivers: Leba, Reda and Radunia. Wiadomossci Parazytologiczne 44 (1): 73-85. [I (2); IV (1)]

Kupchinskaya, Y.S., Kupchinskiy, B.S., Ryzlova, L.N., Tugarina, P.Y. and Tyutrina, L.I. 1983. Biology of the Arctic grayling, *Thymallus arcticus* (Thymallidae), in Ust'Ilim Reservoir. Journal of Ichthyology 23 (1): 47-56. [I (5,7); II]

Kurlykova, O.B. and Makoyedov, A.N. 1995. Intraspecific differentiation of Arctic grayling *Thymallus arcticus,* in northeast Russia. Journal of Ichthyology 35 (9): 220-226. [I (1)]

Lapin, V.I. and Basaanzhov, G. 1989. Seasonal rhythms of physiological-biochemical processes in the Mongolian grayling *Thymallus brevirostris* . Journal of Ichthyology 29 (8): 21-30. [I (1,5)]

Linløkken, A. 1993. Efficiency of fishways and impacts of dams on the migration of grayling and brown trout in the Gomma River system, SE Norway. Regulated Rivers: Research and Management 8 (1,2): 145-153. [I (6); II]

Linlokken, A. 1995. Angling pressure, yield and catch per effort of grayling, *Thymallus thymallus* (L.) and brown trout, *Salmo trutta* L. on the rivers Glomma and Rena, SE Norway. Fisheries Management and Ecology 2 (4): 249-262. [III; IV (3)]

Lohr, S.C., Byorth, P.A., Kaya, C.M. and Dwyer, W.P. 1996. High-temperature tolerances of fluvial Arctic grayling and comparisons with summer river temperatures of the Big Hole River, Montana. Transactions of the American Fisheries Society 125: 933-939. [I (3)]

Lusk, S. 1978. Fish stock and angling in the middle course of the Svratka River. Folia Zoologica, Brno 27: 71-84. [I(1); III]

Lusk, S. 1995. Influence of valley dams on the changes in fish communities inhabiting streams in the Dyje River drainage area. Folia Zoologica, Brno 44 (1): 45-56. [I (1,2; II]

Makoyedov, A.N. 1987. Interpopulation differences and the history of the dispersal of graylings, *Thymallus::* investigation of the variability of dorsal fin coloration. Journal of Ichthyology 27(6): 906-912. [I (1)]

Makoyedov, A.N. 1988. Interpopulational differences and distribution of grayling, *Thymallus :* study of color variation of dorsal fin. Journal of Ichthyology 28 (2): 24-30. [I (1)]

Magee, L. 1993. A review of the grayling *(Thymallus thymallus)* in Yorkshire and some records of transfers of fish and ova. Naturalist 118 (1007): 115-122. [I (1); IV (1)]

Magee, L. 1999. Catch and release. The Grayling Society Journal, Autumn 1999: 14-17. [II; III; IV (3)]

Mallet, J.P., Charles, S., Persat, H. and Auger, P. 1999. Growth modelling in accordance with dally water temperature in European grayling *(Thymallus thymallus* L.). Canadian Journal of Fisheries and Aquatic Sciences 56: 994-1000. [I (5)]

Mallet, J.P., Lamouroux, N., Sagnes, P. and Persat, H. MS. Habitat preferences of European grayling *(Thymallus thymallus* L.) in a medium size stream, the Ain River, France, (submitted Journal of Fish Biology 12 May 1999). [I (3)]

Mann, R.H.K. 1982. The annual food consumption and prey preferences of pike, *Esox Indus,* in the River Frome, Dorset, U.K. Journal of Animal Ecology 51: 81-96. [I (2); IV (4)]

Martel, H. 1999. About big grayling. The Grayling Society Journal, Spring 1999: 41-43. [I (5); III]

Matveyev, A.N., Pronia, N.M., Samusenok, V.P. and Bronte, C.R. 1998. Ecology of Siberian taimen *Hucho taiman* in the Lake Baikal Basin. Journal of Great Lakes Research 24 (4): 905-916. [I (2)]

Martynov, V., Chaput, G., Whoriskey, F. and Anderson, J. 1994. Fishes of the shallow rapids and riffles of the Pizhma River, Pechora River Basin, Russia. Canadian Technical Report of Fisheries and Aquatic Sciences I-VI, 31 pages. [I (2); III]

McKinley, T.R. 1994. Some effects of net-pen-rearing methods on feed conversion by age-0 Arctic grayling in an interior Alaskan lake. Progressive Fish-Culturist 36 (1): 19-24. [IV (1)]

Mitenev, V.K. and Shyl'man, B.S. 1984. Eco-graphic analysis of the parasites of the European grayling, *Thymallus thymallus* (Thymallidae), in various parts of its range. Journal of Ichthyology 24 (5): 125-136. [I (2)]

Mogen, J.T. 1996. Status and biology of the spawning population of Red Rock Lakes Arctic grayling. M.S. thesis, Montana State University, Bozeman, Montana. [I (2,4)]

Nagiec, M., Czerkies, P., Goryczko, K., Witkowski, A. and Murawska, E.C.S. 1995. Mass-marking of grayling, *Thymallus thymallus* (L.), larvae by fluorochrome tagging of otoliths. Fisheries Management and Ecology 2 (3): 185-195. [IV (1)]

Northcote, T.G. 1993. A review of management and enhancement options for the Arctic grayling *(Thymallus arcticus)* with special reference to the Williston Reservoir watershed in British Columbia. B.C. Ministry of Environment, Lands and Parks, Fisheries Branch, Fisheries Management Report No. 101, 69 pages. [II; III; IV (1,2,3,4)]

Northcote, T.G. 1995. Comparative biology and management of Arctic and European grayling (Salmonidae, *Thymallus*). Reviews in Fish Biology and Fisheries 5 (2): 141-194. [I (1,2,3,4,5,6,7); II; III; IV (1,2,3,4)]

Northcote, T.G. 1999. Graylings and The Grayling Society. The Grayling Society Journal, Spring 1999: 7-9. [II; IV (2,3)]

Parkinson, D., Philippart, J.C. and Baras, E. 1999. A preliminary investigation of spawning migrations of grayling in a small stream as determined by radio-tracking. Journal of Fish Biology 55: 172-182. [I (4,6)]

Pavlov, D.S. and Lupandin, A.I. 1994. Response of fish on water currents with different degree of turbulence. Doklady Akademii Nauk 339 (3): 427-430. [I (6)]

Pavlov, D.S., Legkii, B.P, Nechaev, I.V. and Popova, N.K. 1994. Age-related changes of behavior and state of the catecholamine system in the European grayling fry. Investiya Akedemii Nauk Seriya Biologicheskaya (Moscow) O (1): 71 -80. [I (3,6)]

Pavlov, D.S., Lupandin, A.I. and Kostin, V.V. 1994. Downstream migration of fishes from Ust-Khantaisk Reservoir. Journal of Ichthyology 34 (3): 359-365. [I (6); II]

Pavlov, D.S., Nezdolii, V.K., Ostrovskii, M.P. and Fomin, V.K. 1998. Homing in the grayling *Thymallus thymallus* in the basin of the Upper Volga. Journal of Ichthyology 38 (7): 552-553. [I (6)]

Persat, H. 1991. The efficiency of electric fishing in fish population studies: an experiment on grayling *(Thymallus thymallus)*. Verhandlungen Internationale Vereinigung fur theoretische und angewandte Limnologie 24: 2432-2436. [IV (1,2)]

Persat, H. 1996. Threatened populations and conservation of the European grayling, *Thymallus thymallus* (L. 1758). In: A. Kirrchofer and D. Hefti [Editors], Conservation of endangered freshwater fish in Europe. Birkhaeuser Verlag, Basel, Switzerland. [I (2); II]

Persat, H. and Zakharia, M.E. 1992. The detection of reproductive activity of the grayling *Thymallus thymallus* (L.1758) by passive listenung. Archiv fur Hydrobiologie 123 (4): 469-477. [I (4)]

Persat, H and Epper, R. 1997. Alevinage, pollution et cloisonnment de l'espace fluvial dans les structures .... des populations de poisson: L'ombre commun, *Thymallus thymallus,* dans le Rhine an niveau de la Savoie. Bulletin Francais de la Peche et de la Pisciculture 344, 345: 287-300. [I (1,4); II]

Poleo, A.B.S., Ostbye, K., Oxnevad, S.A., Andersen, R.A., Heibo, E. and Vollestad, L.A. 1997. Toxicity of acid aluminum-rich water to seven freshwater fish species: a comparative laboratory study. Environmental Pollution 96 (2): 129-139. [II]

Poncin, P. 1996. A field observation on the influence of aggressive behaviour on mating success in the European grayling. Journal of Fish Biology 48 (4): 802-804. [I (4)]

Popova, I.K., Pavlov, D.S. and Legkii, B.P. 1995. Behavioural mechanisms of primary dispersion in young European graylings *(Thymallus thymallus* L.). Doklady Akademii Nauk 340 (3): 440-443. [I (6)]

Prenda, J., Armitage, P.D. and Grayston, A. 1997. Habitat use by the fish assemblages of two chalk streams. Journal of Fish Biology 51: 64-79. [I (2,3)]

Redenbach, Z. and Taylor, E.B. 1999. Zoogeographical implications of variation in mitochondrial DNA of Arctic grayling *(Thymallus arcticus*). Molecular Ecology 8 (1): 23-35. [I (1)]

Ridder, W.P. 1994a. Arctic grayling investigations in the Tok River drainage during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-19, Anchorage, Alaska. [I (4,5,6)]

Ridder, W.P. 1994b. Contributions of Arctic grayling from Caribou Creek to the Richardson Clearwater River and Shaw Creek, 1980 through 1988. Alaska Department of Fish and Game, Fishery Data series No. 94-49, Anchorage, Alaska. [I (2,4,6); III]

Ridder, W.P. 1995, Movements of radio-tagged Arctic grayling in the Tok River drainage. Alaska Department of Fish and Game, Fishery Data Series No. 95-36, Anchorage, Alaska. [I (3,4,6,7)]

Ridder, W.P. 1998a. Abundance and composition of Arctic grayling in the Delta Clearwater River 1996 and 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-35, Anchorage, Alaska. [I (1,3,4,6,7)]

Ridder, W.P. 1998b. Abundance, composition, and emigration of Arctic grayling in the Goodpaster River 1995-1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-36, Anchorage, Alaska. [I (2,5,6)]

Ridder, W.P. 1998c. Radio telemetry of Arctic grayling in the Delta Clearwater River 1995 to 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-37, Anchorage, Alaska. [I (2,5,6)]

Ridder, W.P. 1998d. Stock status of Chena River Arctic grayling in 1997 and radiotelemetry studies 1997 - 1998. Alaska Department of Fish and Game, Fishery Data Series No. 98-39, Anchorage, Alaska. [I (2,3,4,6); IV (1)]

Ridder, W.P. and D.F. Fleming. 1997. Stock status of Arctic grayling in the Chena River and Badger Slough during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-30, Anchorage, Alaska. [I (2,5); IV (1)]

Ring, O., Jansson, H., Ost, T. and Andersson, T. 1994. Inheritance of allozymes in the European grayling *(Thymallus thymallus* L.). Hereditas (Lund) 120 (2): 159-163. [I (1)]

Roach, S.M. 1994. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 95-9, Anchorage, Alaska. [I (2,5,6)]

Roach, S.M. 1995. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-9, Anchorage, Alaska. [I (2,5,6)]

Roach, S.M. 1996. Influence of electrofishing on the survival of Arctic grayling, chinook salmon, least cisco, and humpback whitefish eggs. Alaska Department of Fish and Game, Fishery Manuscript 96-1, Anchorage, Alaska. [II]

Sabbadini, A. 1985. Study paper to The Grayling Society on impoundment problems in the rivers of northern Italy. [II]

Sagnes, P., Gaudin, P. and Statzner, B. 1997. Shifts in morphometrics and their relation to hydrodynamic potential and habitat use during grayling ontogenisis. Journal of Fish Biology 50: 846-858. [I (3)]

Savvaitova, K.A., Chebotareva, Y.V., Pichugin, M.Y. and Maksimov, S.V. 1995. Abnormalities in the structure of fish as indicators of the state of the environment. Journal of Ichthyology 35 (2): 182-188. [II]

Sempeski, P. and Gaudin, P. 1985a. Habitat selection by grayling. I. Spawning habitats. Journal of Fish Biology 47: 256-265. [I (4)]

Sempeski, P. and Gaudin, P. 1995b. Habitat selection by grayling. II. Preliminary results on larval and juvenile daytime habitats. Journal of Fish Biology 47: 345-349. [I (3)]

Sempeski, P. and Gaudin, P. 1995c. Habitat selection and habitat use by young stages of rheophilic fish species: the grayling model *(Thymallus thymallus,* L.). Bulletin Francais de la Peche et de la Pisciculture O (358): 215-220. [I (3)]

Sempeski, P. and Gaudin, P. 1995d. Construction of habitat preference curves for spawning sites and young stages of grayling *(Thymallus thymallus,* L.). Bulletin Francais de la Pesch et de la Pisciculture O (338): 277-282. [I (3,4)]

Sempeski, P. and Gaudin, P. 1995e. Size-related changes in diel distribution of young grayling *(Thymallus thymallus*). Canadian Journal of Fisheries and Aquatic Sciences 52: 1842-1848. [I (3)]

Sempeski, P. and Gaudin, P. 1996. Size-related shift in feeding strategy and prey-size selection in young grayling *(Thymallus thymallus*). Canadian Journal of Zoology 74: 1597-1603. [1(7)]

Sempeski, P., Gaudin, P., Persat, H. and Grolet, O. 1995. Diet selection in early-life stages of grayling *(Thymallus thymallus*). Archiv fur Hydrobiologie 132 (4): 437-452. [I (7)]

Sempseki, P., Gaudin. P. and Herouin, E. 1998. Experimental study of young grayling *(Thymallus thymallus*) physical habitat selection factors in an artificial stream. Archiv für Hydrobiologie 141 (30: 321-332. [I (3)]

Skopets, M.B. 1988. Biological characteristics of populations of the East Siberian grayling, *Thymallus arcticus pallasi* from upland lakes of the Bol'shoy Annachaz Range (Upper Kolyma). Journal of Ichthyology 28 (5): 124-135. [I (1); II; III]

Skopets, M.B. 1991. Biological features of a subspecies of the Arctic grayling in Northeast Asia. 2. The Alaskan grayling, *Thymallus arcticus signifer* . Journal of Ichthyology 31 (l):46-57. [I (1)]

Skopets, M.B. 1993. Biological features of grayling subspecies in northeastern Asia: III. Eastern Siberian grayling *Thymallus arcticus pallasi*.. Journal of Ichthyology 33 (4): 469-474. [I (1,4,5); III]

Skopets, M.B. and Prokop'yev, N.M. 1990. Biological characteristics of subspecies of the Arctic grayling in Northeastern Asia. I. The Kamchatkan grayling - *Thymallus arcticus mertensi.* Journal of Ichthyology 30 (5): 43-58. [I 91,5,7); III]

Skurikhina, L.A., Tugarina, P.Y. and Mednikov, B.M. 1986. Systematics of Thymallidae (Salmoniformes) based on DNA x DNA hybridization, Journal of Ichthyology 26: 24-29. [I (1)]

Snoj, A., Susnik, S. Pohar, J. and Dove, P. 1999. The first microsatellite marker (BFRO 004) for grayling, informative for its Adriatic population. Animal Genetics 30 (1): 74-75. [I (1)]

Sokalov, L.I. and Tsepkin, E.A. 1998. The headwaters of the rivers of the Moscow region as a refuge for some fish species. Vestnik Moskovskogo Universiteta Seriya XVI Biologiya April-June 1998, 27-30. [I (1); II]

Stanislawski, S. 1994. What defines an Arctic grayling *(Thymallus arcticus*) stream? A review of the literature. Department of Zoology, University of Alberta, Edmonton. 42 pages. [I (3)]

Staub, E., Egloff, K., Kramer, A. and Walter, J. 1998. The effect of predation by wintering cormorants *Phalacrocorax carbo* on grayling, *Thymallus thymallus,* and trout (Salmonidae) populations: two case studies from Swiss rivers. Comment. Journal of Applied Ecology 35: 607-610. [I (2)]

Streu, J.M. 1990. Select aspects of the life history and ecology of the Montana Arctic grayling *(Thymallus arcticus montanus*) (Milner) in the upper Big Hole river drainage, Montana. 32 pages. I 92,3,4,5,6,7)]

Sullivan, M.G. 1988. Status of Arctic grayling in the Northeast Region. Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division, 14 pages. [I (2)]

Sumer, S. 1994. Natual and artificial nutrition for grayling *(Thymallus thymallus* (L.) 1758) fry. Polskie Archiwum Hydrobiologii 41 (3): 279 -284. [IV (1)]

Suter, W. 1995. The effect of predation by wintering cormorants *Phalacrocorax carbo* on grayling *Thymallus thymallus* and trout (Salmonidae) populations: two case studies from Swiss rivers. Journal of Applied Ecology 32 (1): 29-46. [I (2)]

Suter, W. 1997 Roach rules: shoaling fish are a constant factor in the diet of cormorants *Phalacrocorax carbo* in Switzerland. Ardea 85 (1): 9-27. [I (2)]

Suter, W. 1998. The effect of predation by wintering cormorants *Phalacrocorax carbo* on grayling *Thymallus thymallus* and trout (Salmonidae) populations: two case studies from Swiss rivers. Reply. Journal of Applied Ecology 35: 611-616. [I (2)]

Thorfve, S. and Carlstein, M. 1998. Post-stocking behaviour of hatchery-reared European grayling, *Thymallus thymallus* (L.) and brown trout, *Salmo trutta* L., in a semi-natural stream. Fisheries Management and Ecology 5 (2): 147-159. [I (2); IV (1)]

Treasurer, J.W. and Mills, D.H. 1993. An annotated bibliography of research on coarse and salmonid fish (excluding salmon and trout) found in fresh water in Scotland. Freshwater Forum, Freshwater Biological Association, Volume 3, Number 3: 202-236. [I (3,4,6); III]

Tugarina, P.Y. 1972. Systematic position of grayling *(Thymallus*) from the Kamchatka River basin. Journal of Ichthyology 12 (5): 452-463. [I (1)]

Tugarina, P.Y. and Khramtsova, V.S. 1980. Redescription of the Amur grayling, *Thymallus grubei.* Journal of Ichthyology 20 (4): 10-15. [I (1)]

Tugarina, P.Y. and Khramtsova, V.S. 1981. The ecology of the Amur grayling, *Thymallus grubei.* Journal of Ichthyology 21 (1): 10-25. [I (1,5,7)]

Valentin, S., Sempeski, P., Souchon, Y. and Gaudin, P. 1994. Short-term habitat use by young grayling, *Thymallus thymallus* L., under variable flow conditions in an experimental stream. Fisheries Management and Ecology 1: 57-65. [I (3)]

Volubuev, V.V. and Rogatnykh, A.Y. 1999. Ecology and population structure of the Siberian grayling *Thymallus arcticus* in continental basins of the Sea of Okhotsk shore. Journal of Ichthyology 39 (1): 125-130. [I (1,2,3,5,6,7)]

Vuorinen, P.J., Keinanen, M. and Peuranen, S. 1998. Effects of iron, aluminum, dissolved humic material and acidity of grayling *(Thymallus thymallus)* in laboratory exposures, and a comparison of sensitivity with brown trout. Boreal Environmental Research 3 (4): 405-419. [II]

Wilson, R., Allen, G.S., Griffin, D. and Landers, D. 1995. Organochlorine contaminants in fish from an Arctic lake in Alaska. Science of the Total Environment 160-161: 511-519. [II]

Wuttig, K.G. 1997. Successional changes in the hydrology, water quality, primary production, and growth of juvenile Arctic grayling of blocked Tanana River sloughs, Alaska. Masters thesis, University of Alaska, Fairbanks. [II]

Zeh, M. and Donni, W. 1994. Restoration of spawning grounds for trout and grayling in the river High Rhine. Aquatic Sciences 56 (1): 59-69. [I (4); II; IV (2)]

LIST OF FIGURE CAPTIONS

Fig. 1. The generalized world distribution of graylings.

Fig. 2. Annual mean publication rate of scientific papers and technical reports on grayling since the mid 1800s.

Fig. 3. Regional percent partitioning by "species" of 186 recent[a] references on grayling into four broad subject areas using totals above each subject area. References on Arctic grayling separated into North America ans Siberian / Asian contributions.[a] 122 are from 1995 to 1999.

Fig. 4. Regional percent partitioning by "species" of 158 recent references on grayling biology into seven general subject areas. Other details as for Fig. 3.

Fig. 5. Regional percent partitioning by "species" of 46 recent references on grayling management into four general subject areas. Other details as for Fig. 3.

Arctic grayling *Thymallus arcticus*
Extinct populations
European grayling *Thymallus thymallus*

Species status uncertain *Thymallus ?*

Fig. 1

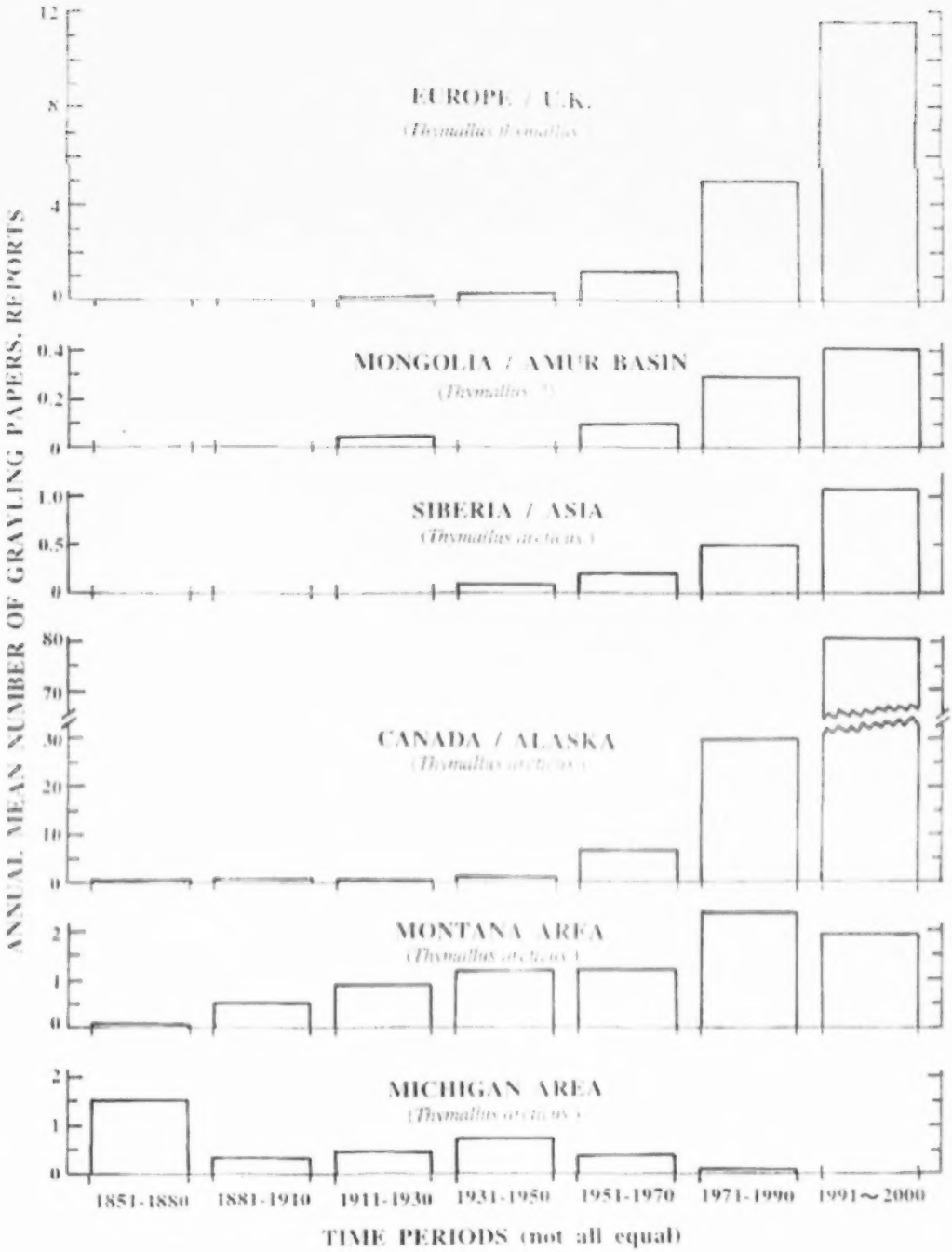
ANNUAL MEAN NUMBER OF GRAYLING PAPERS, REPORTS
EUROPE / U.K.
MONGOLIA / AMUR BASIN
SIBERIA / ASIA
CANADA / ALASKA
MONTANA AREA
MICHIGAN AREA
1851-1880
1881-1910
1911-1930
1931-1950
1951-1970
1971-1990
1991~2000
TIME PERIODS (not all equal)

Fig. 2

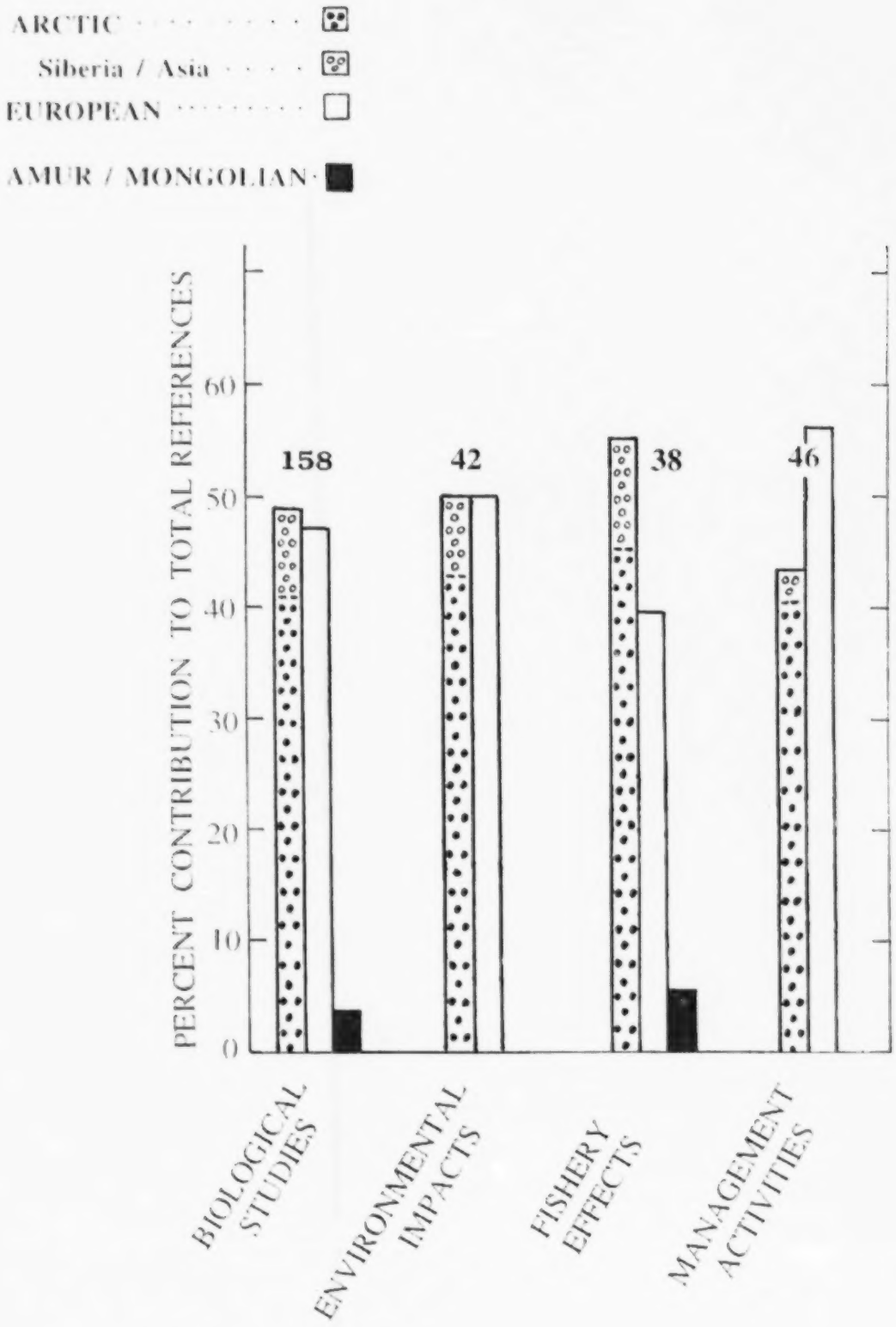
ARCTIC
Siberia / Asia
EUROPEAN
AMUR / MONGOLIAN
PERCENT CONTRIBUTION TO TOTAL REFERENCES
0
10
20
30
40
50
60
158
42
38
46
BIOLOGICAL STUDIES
ENVIRONMENTAL IMPACTS
FISHERY EFFECTS
MANAGEMENT ACTIVITIES

Fig. 3

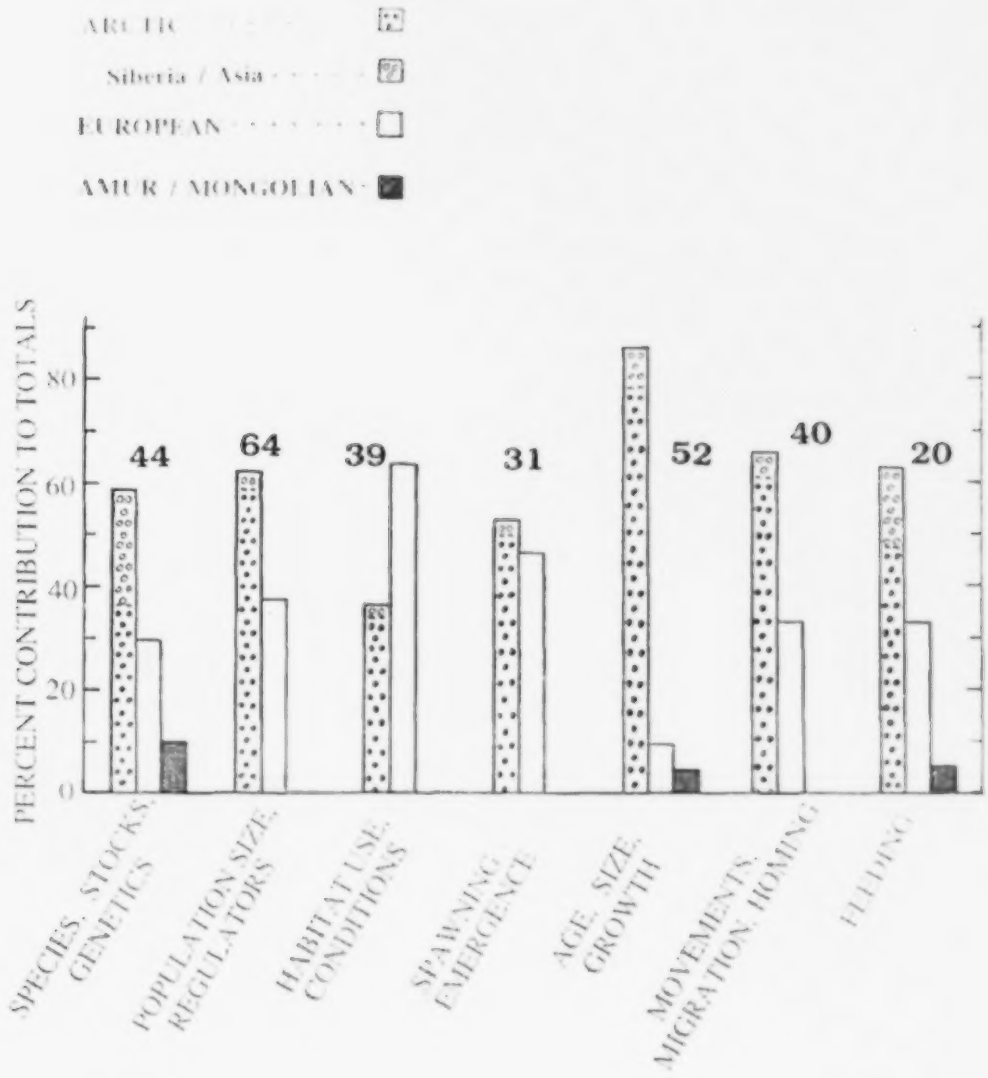
ARCTIC
Siberia / Asia
EUROPEAN
AMUR / MONGOLIAN
PERCENT CONTRIBUTION TO TOTALS
0
20
40
60
80
44
64
39
31
52
40
20
SPECIES, STOCKS, GENETICS
POPULATION SIZE, REGULATORS
HABITAT USE, CONDITIONS
SPAWNING, EMERGENCE
AGE, SIZE, GROWTH
MOVEMENTS, MIGRATION, HOMING
FEEDING

Fig. 4

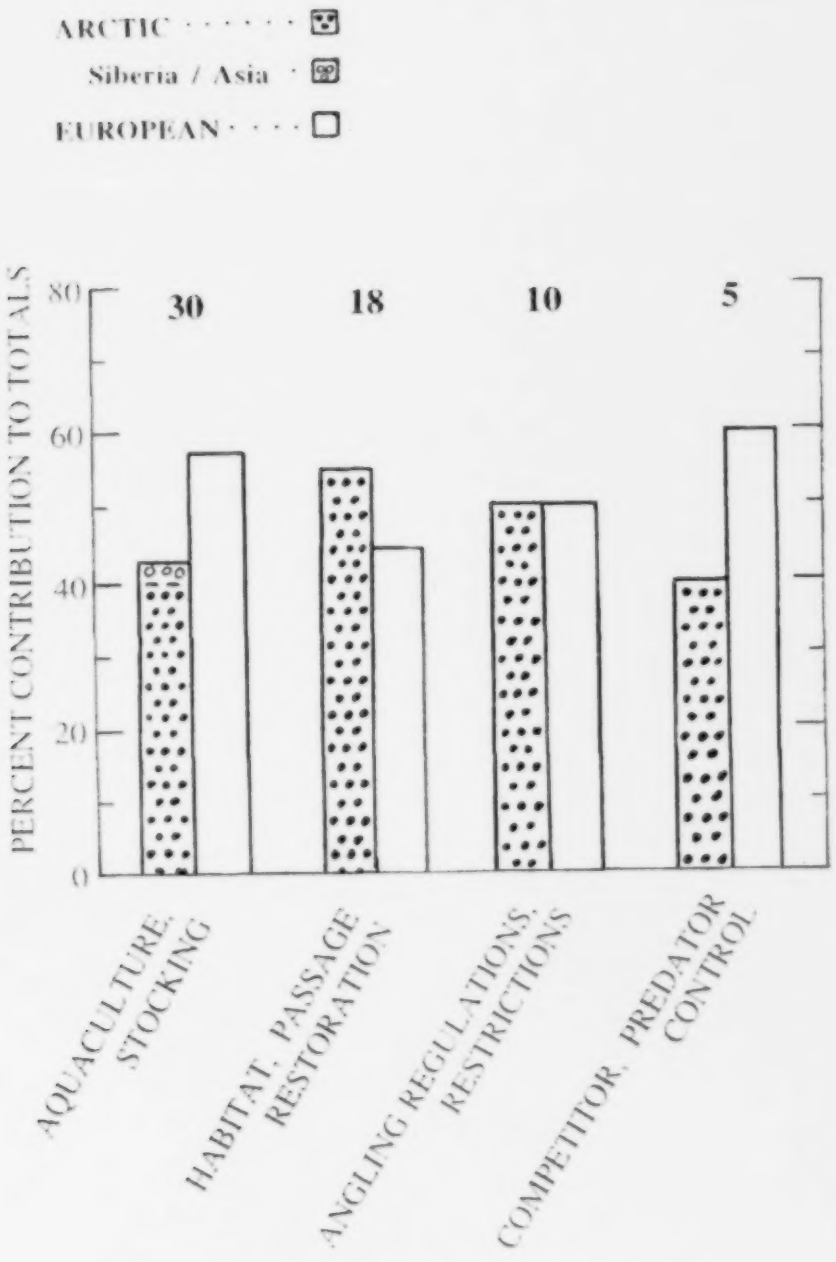
ARCTIC
Siberia / Asia
EUROPEAN
PERCENT CONTRIBUTION TO TOTALS
80
60
40
20
0
30
18
10
5
AQUACULTURE, STOCKING
HABITAT, PASSAGE RESTORATION
ANGLING REGULATIONS, RESTRICTIONS
COMPETITOR, PREDATOR CONTROL

Fig 5